

TITLE: Soviet Supersonic: A Technopolitical Disaster

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VOLUME: 28 ISSUE: Winter YEAR: 1984

STUDIES IN INTELLIGENCE



A collection of articles on the historical, operational, doctrinal, and theoretical aspects of intelligence.

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~~SECRET~~ (b)(3)(n)*A tuft of golden plumage***SOVIET SUPERSONIC: A TECHNOPOLITICAL DISASTER**

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In the Russian fable of the Firebird, the Tsarevitch becomes intoxicated with a bewitching birdlike creature who dances in the wilderness. He tries to capture her secrets, but comes away bearing only a tuft of her rich golden plumage. The Firebird, the tantalizing beauty, escapes, her elusive mysteries intact, having stolen the golden apples that provide the sustenance of the Russian realm. ...

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[redacted] analysis of the USSR's supersonic airliner project provides insights into Soviet institutional interaction, elite psychology, and the strengths and weaknesses of Soviet research and development. The TU 144's origins can be traced to 1961; its end was announced in the summer of 1984. Many elements of this twenty-three year development program remain obscure.

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Obscure Genesis: 1961 - 1971

The first impression affecting an analyst approaching the Soviet SST story is the dramatic imbalance of materials available for its first and second decades. While the final days of the Soviet SST project can be reconstructed in great detail, its beginnings cannot.

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[redacted] The TU 144 story in the 1960s must be reconstructed from contemporary press commentary and flashbacks from later reporting. The critical questions remain:

- Why did the USSR follow the West into supersonic transport development?
- Which Soviet institutions played leading motivational roles in bringing this about?

The atmospherics of the last years of Nikita Khrushchev's rule were radically different in spirit from those which have followed. Khrushchev was an adventurer, sincerely hopeful that Soviet technological prowess—revealed

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most dramatically by the advent of Sputnik in 1957—would enable the Soviets to surpass the West by 1980. Soviet space successes seemed to accredit the Soviet elite's technocratic optimism. An airliner of unprecedented speed to conquer the USSR's unparalleled distances must have seemed the wave of the future.

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This Soviet "crash" program, which attained dramatic early results, was a first-class technical achievement. It had been accomplished chiefly by mobilizing the entire Soviet aerospace establishment behind Tupolev, by commission of the Council of Ministers. It is a salient example of the Soviet economy's ability to deliver quickly by concentrating all resources on a given design goal. Only later did the cost of this strategem become apparent.

For example, the development approach to the SST was that of the "Great Leap Forward." There was not time to develop sub-systems at a correct, safe rate and then integrate them into the grand design. Rather, all design components were developed simultaneously at maximum speed, which led to corner cutting and some high-risk technical solutions. This produced early results for the record books, as the higher party leadership doubtless desired, but it did not deliver reliable components for a project as technically ticklish as a supersonic airliner.

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The trouble-plagued history of the struggle to place the TU 144 into commercial service may be traced to the Central Committee's decision to concentrate on a record breaker. Fourteen years of dogged development, system modification, and redesigns never compensated for an inappropriate project strategy. Subsequent efforts to put the aircraft right were not aided by

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the fact that Tupolev's rival design bureaus were forced, for policy reasons, to act as its unacknowledged subcontractors.

The priority accorded the SST is shown by comparing its progress over the Backfire bomber, with which it shares Kuznetsov NK-144 engines.

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It eventually became apparent that the Backfire Mach II b

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shared more with the SST than its engines. Target speed, probable weight, and, probably, landing gear design were similar.

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As aerospace was the first priority in Soviet technical espionage in the 1960s, and the SST was the first priority project of the sector, the TU 144 quickly benefitted from data collected by Soviet intelligence services.

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In the case of the SST, an analogous project was proceeding in the West in an atmosphere of high publicity; this made matters much easier.

Something of the magnitude of this activity is revealed by General de Gaulle's personal authorization of the expulsion in 1965 of Sergei Pavlov, then senior Aeroflot representative in Paris. Pavlov spent much of his time attempting to penetrate SudAviation facilities near Toulouse to learn the secrets of the Concorde. In this, Pavlov appears to have been successful. His expulsion did not damage his career; he rose eventually to become Deputy Minister of Civil Aviation.

Pavlov recruited two French Communist Party members working at Toulouse to obtain blueprints and plans. At the trial of two Czechoslovakian priests in March 1966, arrested near the factory, one of the clandestine transmission routes of Concorde data was revealed. Microfilmed plans had been rolled up in toothpaste tubes by "tourists" on the Ostend-Warsaw Express for forwarding to Moscow.

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This is in part a tribute to the efficacy of the "gumshoe" developed by Soviet intelligence services, whereby Soviet delegations visiting Western machine shops and production lines wore shoes with super-soft and absorbent soles designed to pick up and retain metal filings and samples from the floor.

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Technology theft also took cruder forms, even in the spotlight of detente.

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The Soviets were known to have problems casting blades. Important Soviet officials were told these parts could not be sold. Shortly thereafter, most of the exhibit, including the uniquely perfect compressor casting, was stolen.

The Soviet SST made its debut at Sheremetyevo Airport, Moscow, on 21 May 1971. As the leadership had endowed the aircraft with a priority over defense projects, it was almost without precedent and indicative of Soviet optimism that the public was permitted to inspect this aircraft, embodying Soviet state-of-art technology.

More suprisingly, the leadership decided to fly the aircraft to Western air shows where it would be subject to detailed scouting by Western technicians. The TU 144's presence at the Hamburg Air Show in 1972, and the Paris shows of 1971, 1973, 1975, and 1977, provided opportunities for detailed inspection of the latest Soviet technology. This put Soviet aerospace development and production techniques into fresh focus. Frank peer exchanges between Soviet and Western pilots, engineers, and designers yielded information and insights extending beyond the SST proper. Politburo pride in this superlative Soviet technical achievement overrode normal Soviet preoccupations with secrecy and security.

Hidden Costs

In the context of the several long interruptions in SST testing—from 1 January to 30 March 1969, from 1 November 1969 to 1 April 1970, and from 12 November 1970 to 1 April 1971—the decision to go public with the craft reflects a certain bravado. The Soviets in this instance were breaking with precedent in not copying the West, but carrying out development in parallel. For once, the Soviets were toiling alongside the West at the technological frontier. Western technical secrets frequently could not be exploited because of inadequate Soviet materiel and technique as well as inability of Soviet engineers to decipher Western technical data. This undercut extensive Soviet technical espionage. Therefore, high level pressure to develop the SST at top speed at all costs had a counterproductive effect.

Soviet engineers themselves—including chief designer Alexei Tupolev—subsequently complained that concentration of Soviet resources on the SST blighted more economically justifiable programs, notably the wide-body jetliners that the USSR badly needed for the 1970s and 1980s. The first of these, the IL-86, was supposed to serve the 1980 Olympics, but was not available in quantity.

Record Breaker Goes Public

The first appearance of the TU 144 in the West, at Paris in June 1971, took place the week following the US Senate vote, 49 to 47, not to underwrite

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the development of an American SST. The Senate vote disquieted Soviet SST proponents

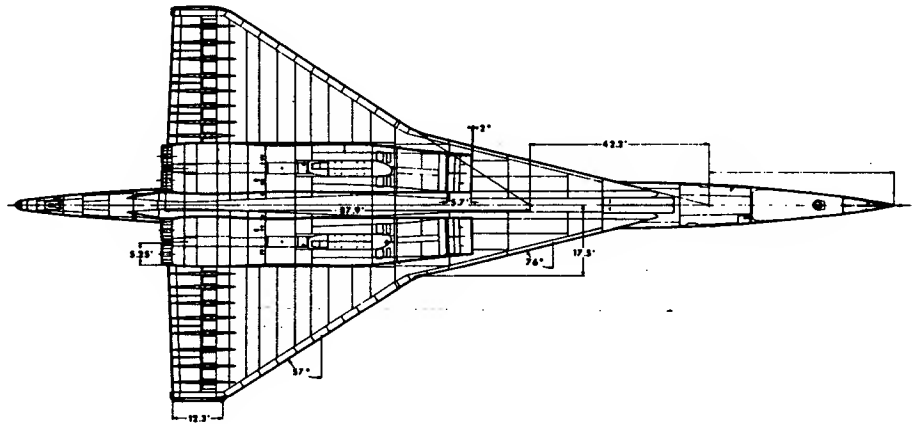
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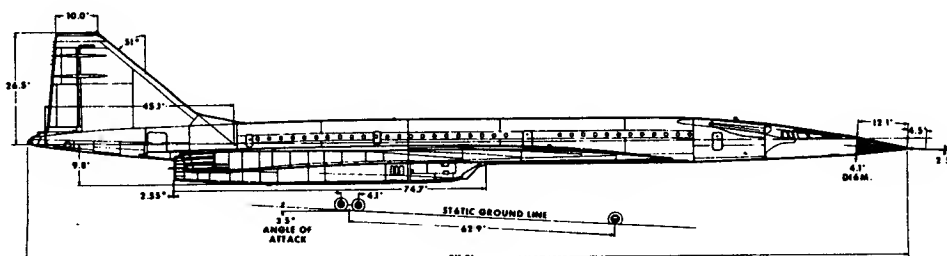
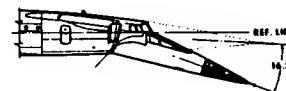
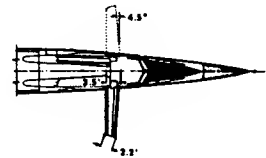
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Tupolev engineers that Alexei Tupolev was the chief motivator and lobbyist for the SST project, and indicates that as early as 1971, Tupolev was well aware that the ruinous concentration of Soviet aerospace assets on the SST had stalled more necessary projects.



Bottom, side, and auxiliary views of the TU 144, with dimensions. Top view of nose section shows canards extended.

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At Orly, though the TU 144 was carefully guarded by the Soviets, Western experts were able to approach the aircraft and observe signs of operational stress. The Soviets obviously took a casual approach to presentation: popped rivets, missing bolts, and wrinkled, heat-stressed skin were apparent. The threadbare tires, often with cord showing, provided eloquent testimony that Soviet tire technology could not meet the challenge of 121 tons repeatedly landing at 175-180 miles per hour.

Numerous meetings of Western and Soviet aerospace specialists from 1971 on revealed the contrasting personalities of chief test pilot Eduard Elyan and chief designer Tupolev. Elyan, visibly contemptuous of his accompanying security goon, was delighted with an opportunity to sit in an F-16 cockpit, and was personally solicitous of a US test pilot who had recently crashed. Elyan, whose "Hero of the Soviet Union" medal denoted a survivor of three crashes or near misses, asked whether the American had back pains, as he, Elyan, had suffered for months as a consequence of a wheels-up landing.

Tupolev was a less sympathetic, if more complex personality. Warming to his role as TU 144 flack, he retailed official howlers even before audiences who knew better. He told one group of visiting engineers that the TU 144 was "17 percent quieter than Concorde." Tupolev had his own reasons for backstopping the mendacious official line. His own father had been arrested by Stalin's secret police in 1937 as a "wrecker," in a bizarre backwash of the Great Purge, and confessed immediately to avoid torture. Thereafter, Tupolev *pere* and most of his chief engineers designed aircraft in a unique Soviet institution, the "sharashka," or prison bureau.

Western delegations began to visit the TU 144 remote assembly plant at Voronezh. The first known pilgrimage of this type was undertaken by the president of Aerospatiale in 1971. Later US visitors were impressed by Soviet titanium skin work, in particular the practice of winding the one-piece wing skin 360 degrees around its spars. This technical advancement jarred with the density of machine tools at the facility, said to be five times those found at an analogous US facility—reminiscent of American conditions in the 1930s.

Whether this reflected a Soviet fetish for the machine shop and/or backwardness in Soviet forging technology was unclear, but intensive "hogging out" (machining from the solid) of titanium ingots produced a useful yield of only ten to twenty percent. The considerable waste from this process was sold to US scrap dealers. Later scrap analysis indicated that the TU 144 shared at least one component with the IL-86.

Juxtaposition of the modern with the primitive was capped by an automated chicken coop adjacent to the TU 144 assembly area; the Soviets showed this off as an example of Tupolev's "diversification."

Elsewhere, Soviet standards were notable by their absence. US production engineers were astounded to learn that Russians had no term for "reliability engineer." "Life cycle testing," whereby components were tested to destruction, likewise had no place in the Soviet lexicon or experience. Western executives visiting Aeroflot were appalled at the lack of any mechanism to track operating costs, and the absence of a balance sheet.

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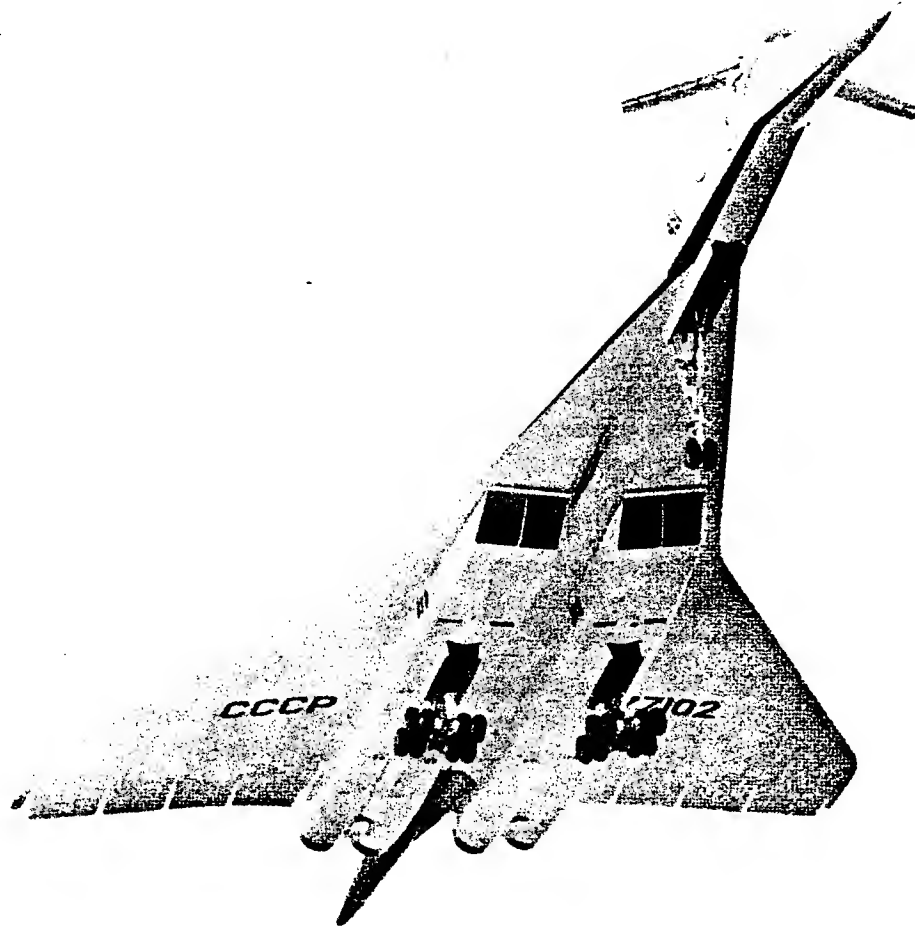
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Final Product and First Crash

The "production" TU 144 which appeared at the 1973 Paris Air Show differed dramatically from the earlier prototypes. Had it been developed in the West, it probably would have been assigned a new design number. Chief designer Tupolev later noted that the new version was ten percent longer than the prototype, with seven percent more wing area. More tellingly, the wing had been completely redesigned into a "double delta" configuration, supplanting the curved leading edges of the prototype. Two canards—short stub wings that swung out from the nose—aided quick lift-off, at the cost of increased weight and drag. The four NK-144 turbofans were moved outward from their original placement in the lower fuselage to the wing roots. The landing gear was moved down from the engine nacelles and its geometry was extensively revised, from three- to two-axle configuration.



TU 144B in flight at Paris Air Show, 23 May 1973.

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In short, the "production" TU 144 was almost a new aircraft. A Western engineer/designer who had walked through the prototype the previous year described the 1973 version as a "complete redesign," with a new wing-engine relationship. The large landing gear housing was eliminated and the fuselage cross-section had been changed from an oval to a full circle. The tail section had been lengthened twenty-five feet. The modifications reflected a serious Soviet re-examination of the TU 144 after it had flown only two hundred hours. In sum, the TU 144 now resembled the Concorde more closely. The Soviets by now were troubled that the Concorde project had overtaken their own.

This TU 144, the second of the "production" batch, ended its debut in the West spectacularly by exploding in mid-air on the last day of the Paris Air Show, 3 June 1973.

The post-mortem involved examination of the smallest details. One US expert described the disposition of a missing bolt in the left tail section. Another testified that the color of the metal used in the fuselage had changed at the point where the tail section had separated from the fuselage in mid-air. Soviet test pilots later confirmed the observation by a Western engineer that the TU 144 had no "G leveling"—there were no overrides on the controls that prevented it from being maneuvered and stressed beyond the structural limits of the airframe.

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But this detailed technical analysis was beside the point: the crash was rooted in political and psychological pressures, not technical failure. As Soviet experts explained to Western test pilots in 1974, the crew at Paris in 1973 was under incredible official pressure to make the commercial debut of the production TU 144 as dramatic as possible. Confronting the Concorde was in line with the Soviet elite's "catch up" policy. The TU 144 maneuvering over the airport that final weekend of the air show, interesting to the average observer, was described by an expert eyewitness as "spectacular . . . risky and overdone." The huge aircraft was thrown into perilously sharp turns at minimum speed and altitude, for maximum show effect.

The aircrew, obeying orders to make the aircraft's debut as spectacular as possible, paid with their lives. According to Viktor Suvorov, the Politburo took an intense interest in the crash. GRU films of the crash were rushed to Moscow for viewing by the Politburo the next morning, where the inquest featured evidence from Tupolev, his deputies, and Soviet intelligence agencies. The GRU, which had twenty films of the crash, was reportedly begged by the KGB's Andropov for "just one" reel to illustrate his report, and was turned down. Leadership complicity in the crash found cathartic expression through a collective front page obituary in *Pravda* which announced a posthumous shower of decorations for the heroes. The fate of five French citizens, killed when tons of incandescent metal rained down upon their village, was not mentioned.

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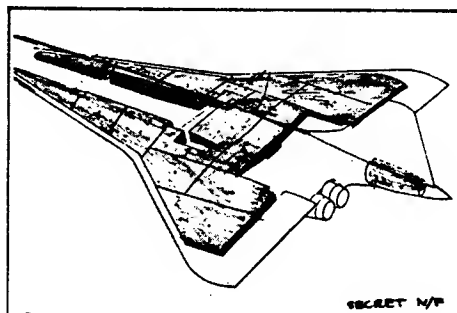
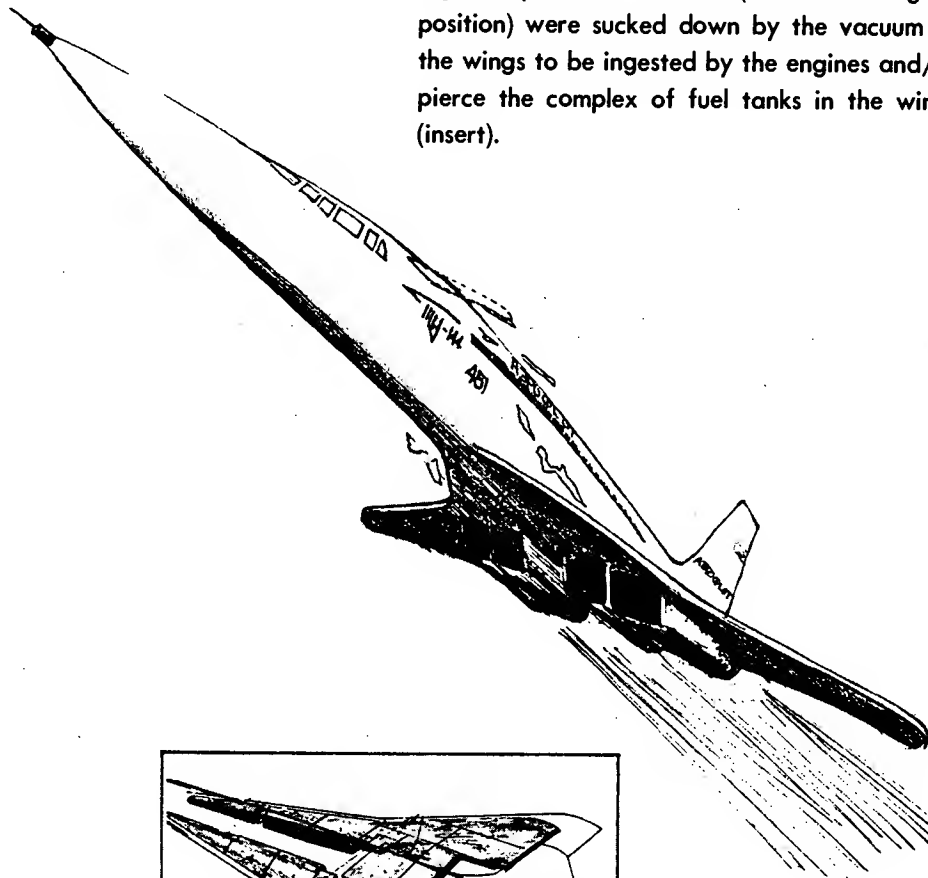
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The immediate cause of the disaster was that the pilots put the TU 144 into a steep climb immediately after a pass over the runway. The afterburners, which earlier had been observed to stutter and sometimes catch only on the third or fourth engine rev-up, cut in unevenly. This overstressed the airframe, designed for fast, level flight rather than abrupt low speed test maneuvers. It is believed that the noseplanes, or canards, then disintegrated, the pieces penetrating the twenty wing fuel tanks and possibly being sucked into the fifty-nine-inch diameter inlets of the engines, which subsequently exploded. The nose of the aircraft was thrown forward and down and the tail backward and up. The conflagration was reminiscent of the Hindenburg thirty-six years before; it, too, blew apart in the air, a pioneering form of air transport

This drawing depicts the beginning of the end for the TU 144B, Number 2, in the air near Paris on 3 June 1973. Pieces of the disintegrating nose planes, or canards (outlined in original position) were sucked down by the vacuum of the wings to be ingested by the engines and/or pierce the complex of fuel tanks in the wings (insert).

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embodying the hopes of a totalitarian technocracy and dying a fiery public death.

There were at least two inquests; in neither case were the findings publicized. The Soviet inquest, probably carried out jointly by the Ministries of Air Industry and Civil Aviation, assigned cause of the crash to "pilot error" or "human factors." TU 144s in the USSR were grounded for some months and production at the Voronezh factory was halted. Resumption of flight testing after eight months with apparently unmodified aircraft indicates that the aircraft itself was cleared from the Soviet point of view. As late as 1977, chief designer Tupolev * and Soviet test pilots refused to discuss the crash or the subsequent investigation, claiming that it was "still under investigation."

The French Concorde evaluation group also studied the crash. The French found that the pilot had gone into a stall and used too much afterburner to compensate, overstressing the engine and breaking loose the canards. These findings were not made public: the crash of the TU 144 cast a shadow on the Concorde project, now under political pressure because of its great cost, high fuel consumption, and perceived environmental impact.

Soviet Approaches to France and the UK

The TU 144 appeared at four Paris air shows, never at the British counterpart at Farnborough. Following the visit of Aerospatiale President Ziegler to Voronezh in 1971, a Franco-Soviet Joint Working Group exchanged data on SST developmental problems. Official Soviet delegations were admitted to Concorde production facilities at Toulouse to gather documentary information and indulge in intensive photography and measurement of components. The French rationalized that cooperation provided them an edge "over other competitors in the West" and might lead to sales within the USSR. After the French discovered Soviets scraping metal off the Concorde's engines in 1978, however, matters lapsed into "abeyance." A French proposal to fly Concorde nonstop through Soviet airspace to Tokyo, three months after the second TU 144 crash in 1978, was turned down by the Soviets, ostensibly because of concern that the Concorde would degrade Siberian ecology. Western observers were convinced the real reasons were Soviet security considerations, as well as pique that all TU 144s were again grounded.

British dealings with the Soviets were frostier. Relations lay under the cloud of the mass expulsion of one hundred and five Soviet intelligence officers from London in 1971

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The TU 144's true supersonic range fell short of Concorde's by about one thousand miles. TU 144 was only a medium range SST, not a true commercial competitor to the long range Concorde.

* The TV pool film provided a good picture of the mid-air explosion, but failed to identify the stricken chief designer arriving at the crash site.

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Indications of trouble also registered in comparing hours-in-air: although the TU 144 had first flown three months before the Concorde, by 1972 it had logged only seven hundred hours of developmental flight, versus fifteen hundred for the Concorde.

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The Concorde's purchase price per seat was said to be ten times that of a modern subsonic airliner; operating cost per passenger-mile would be twice as much. Concorde fuel consumption was estimated at three times that of a normal airliner. Cost weighed heavily upon commercial decisions to buy Concorde and undercut even more the prospects of the larger, heavier, and demonstrably thirstier TU 144.

The Soviet SST was also hampered by Aeroflot's poor reputation for provision of spares and overseas repair facilities, which for the TU 144 were centralized in Moscow even on internal routes.

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In the late 1960s the Soviets had already mounted an assiduous, if ultimately fruitless, courtship of British Concorde engineers, featuring weekly invitations from the Soviet Embassy in London to meet with Soviet "colleagues" who "happened to be in the area." The Soviet apparatus had early identified Concorde's engines as the critical collection target. Soviet Kuznetsov turbofans came to surpass the Rolls Royce-Bristol engines in sheer thrust, but only through ruinous near-permanent use of after-burners, whose heat fatigued TU 144's skin and airframe. This high speed bomber engine was heavy, smoky, and gluttonous, so much so that it is doubtful whether the TU 144 could have crossed the Atlantic more than half full of passengers.

Because Tupolev pushed mainly for greater power, engine efficiency received short shrift. In 1975 the Soviets approached the British firm Lucas Aerospace, discussing a \$17-million contract for a modified version of the digital fuel injection system used on the Concorde. Typically, initial Soviet data furnished on NK-144 performance characteristics contained falsified information. Lucas engineers corrected the data based on what they knew, and Soviet experts corrected the corrections in a series of "give and take technical sessions." The chief intelligence gain from these talks was to confirm in greater detail the design faults of the engine, whose internal "blow in" and "blow out" doors were designed to open and close at different times. Lucas concluded that the NK-144 was incapable of optimum operation at any speed.

Further evidence of Soviet research and development failings was provided by the Soviet insistence on the use of a hodgepodge of obsolete Western engine control equipment, an admixture of both electronic and hydromechanical components, samples of which the USSR had assembled through both legal and clandestine purchases. What the Soviets were "ordering" was not the state-of-the-art equipment of maximum possible benefit, but production tech-

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nology for manufacturing complex, obsolete, and somewhat incompatible systems. A bemused Lucas management supported such a sale, arguing it would protect the Western lead in a vital area. These bizarre negotiations proceeded for two years, then were halted by the British in 1977.

Chief designer Tupolev, aboard the TU 144 during its last visit to the West at the 1977 Paris Air Show, had lost much of his earlier ebullience. He had no idea when Soviet authorities would authorize the beginning of the TU 144's commercial service. He personally would be just as happy to stay with high-speed air freight, as passengers were just "too much trouble." By now the Tupolev entourage was more forthcoming regarding the noise problem, which afflicted ground crew, passengers, and residents. This necessitated flying the aircraft to remote airports.

Commercialization

Until the mid-1970s it appeared that the TU 144 might emerge as a credible competitor to Concorde; Soviet advertising followed this theme until 1976. Tupolev's glumness by 1977 reflected the fact that the TU 144 had now demonstrably fallen behind the Concorde. TU 144 route testing had begun in May 1974 and scheduled flights of freight and mail on 26 December 1975, just before the launch of Concorde's first two international routes in January 1976. Air France and British Airways officials, noting that no flight schedules or rates were available, dismissed this as "a propaganda exercise." Over the next two years fifty TU 144 freight runs were carried out, and eight were canceled.

Ultimately, *raison d'etat* prevailed over the realities of the troubled test flight program. In October 1977 the TU 144 reportedly received its airworthiness certificate from a new Soviet authority, said to be set up on the lines of the US Federal Aviation Administration. This bureaucratic convulsion may be related to TU 144 travails. Previously, each design bureau had certified its own aircraft as ready for use. The sparse documentation forwarded by the Soviets was deemed inadequate by Western experts for air certification in their countries. But within the USSR, the way was clear for supersonic "commercialization."

Coincident with the Diamond Jubilee of the Great October Revolution, Soviet SST passenger service was launched 1 November 1977, twenty-two months behind Concorde. This was a first rank Soviet media event, marred only by the breakdown of the motorized embarkation ramp, which—to the observable fury of Minister of Civil Aviation Boris Bugayev—delayed departure for thirty minutes.

This was a rare opportunity for Westerners to sample the aircraft in flight. Only two of the 113 passengers paid the \$110 fare to Alma Ata; officially selected reporters and photographers comprised the remainder. Their chief impression was of the cacophony created by the monstrous air conditioners, the rush of air, and the huge engines. The rear of the cabin was unbearable; elsewhere, conversations were shouted. Because Aeroflot flights were "classless," the survival of a first class cabin suggested that hope lingered for international service. The 2,025-mile trip was completed in exactly two hours, with take-off noise estimated at 110 decibels.

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Possibly laundered Soviet documentation provided to the Franco-Soviet Joint Working Group recorded 226 faults in the 102 flights undertaken between 1 November 1977 and 1 June 1978. The most dramatic of these were a sudden loss in cabin pressure on 27 December and that on 24 January the landing gear light had stayed on. The real problem was that the TU 144 was not recovering costs on its single domestic route. The Concorde by now was in service on seven international routes and at least operationally profitable on most of them.

The most basic problem—thirsty engines—remained. Reports had filtered out during the 1970s of new engines for the TU 144, possibly turbojets on the lines of the Concorde with smaller inlets and nacelles. This suggestion seems not to have been developed. By the mid-1970s, reports came out of a “variable geometry, variable by-pass ratio” engine under development by the otherwise obscure Koliesov Design Bureau. This engine was said to function as a turbojet subsonically and as a turbofan supersonically, providing optimum efficiency in both regimes. [redacted] later concluded that a variable cycle engine was “an exceedingly complex scheme considered beyond current Soviet design capability.”

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Reports nonetheless began to emerge of a new series TU 144D, fitted with a new type of engine “fifty percent more economical.” One of the first of these aircraft, with Soviet premier test pilot Eduard Elyan presumably at the controls, crashed the afternoon of 23 May 1978.

The news seeped out slowly to the West. Aeroflot in June “confirmed” that flights had been suspended, ending eight months of passenger service. Rumors circulating among Tupolev personnel indicated that a fire broke out in the left engines and spread to the fuselage. The pilot was said to have successfully shut down one or more engines, but came down in a field when power failed and he could not maintain altitude. The SST was gutted by burning fuel and was then blown apart. Some time after the fact, Western aviation magazines reported that three crew members were burned to death and two survived. Voronezh gossip set these numbers at nine and two, respectively. Whether the pilot survived is unknown in the West. [redacted]

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[redacted] reporting as late as 24 October 1978 was tentative.

Official confirmation of the crash had in fact been made to the French during the Joint Working Group meeting of 11 October. The Soviet spokesman admitted under questioning that there had been a TU 144 crash, “but it was not an aircraft belonging to Tupolev or Aeroflot.”

At the 11 October joint meeting with the French, the Soviets produced a document described by one participant as a “cry for help.” Confirmation of the crash was followed by the “confidence” that Tupolev had recommended suspension of service to Alma Ata before the crash occurred, owing to high levels of noise and fuel consumption. Development flights were continuing; regular passenger flights would resume within “months rather than years.” There were no references to engine problems as such. But there was a litany of shortcomings that may have reflected a crash post-mortem: ice forming around engine inlets, leaky fuel pipe connections, and an emergency on-board power supply for the aircraft. The skin had fatigued, with cracks forming at the base

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of the fins and in the thin foil lining the wheel bay ahead of the nose gear, probably owing to heat or insufficient cooling or, possibly, acoustical cracking. The French responded that if they could provide technical aid, their British partners would have to be consulted. There the matter presumably rested.

The disaster of 23 May 1978 compounded the fearsome reputation of the TU 144 among the workers responsible for assembling it. Rumors abounded of further crashes and flights aborted because of last-minute malfunctions. A third crash, unreported by Soviet authorities, was believed to have occurred at the end of a Moscow-Alma Ata run in 1974. The Bolshoi Ballet, it was said, had escaped death only by transferring to another aircraft at the last minute.

Behind the Scenes Again: 1978-84

The second crash marked the beginning of the end for the TU 144. Ominously, the TU 144 began to disappear from the lists of future Soviet aircraft mentioned in the Soviet press. *Komsomolskaya Pravda*, observing the sixtieth birthday of Tupolev in November 1978, made the admission—startling in the Soviet context—that “ideas and technical solutions developed by Tupolev for military bombers were not readily translatable to airliners where considerations of economy, comfort, and reliability were paramount.” This was not the SST’s epitaph, but it may justly be regarded as the Soviet media’s high water mark of candor. In December Sergei Pavlov, Deputy Minister of Civil Aviation, who a decade before had organized the abstraction of Concorde blueprints from Toulouse to Moscow, conceded to Ambassador Hartman that the aircraft was experiencing “considerable difficulty.” Its thirty-percent ticket premium did not even cover operating costs. By late 1978 Aeroflot had launched a fuel conservation program nationwide and the politically important export of kerosene to its major market, India, was being suspended during August, peak month of Aeroflot operations. Odds were against the TU 144, a confirmed dipsomaniac even operated subsonically.

The remaining life of the TU 144 was played out as it had begun: as a Soviet propaganda vehicle. On 23 June 1979 Soviet media announced that a TU 144 had flown the 4,350 miles from Moscow to Khabarovsk in three hours and twenty-one minutes, to commemorate the fortieth anniversary of the first nonstop flight (by a Tupolev) from Moscow to the Far East. On 4 March 1980 the TU 144 made its last appearance in the Soviet media and the record books. Number 77106, which had inaugurated commercial flights, was flown to the Soviet Air Force Museum at Monino, near Moscow. Even in retirement, it acquired one final garland: it was the first supersonic airliner to land on dirt, using a sod runway frozen and extended for this special occasion. Three drag chutes brought it to rest in less than a kilometer of run-out. This curious occasion reflected an ancient Aeroflot requirement that all its equipment be designed to land on dirt.

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While most TU 144s remained grounded for long periods, they were occasionally observed being fitted with new engines. In March 1981 engine work was in progress on four TU 144Ds, and in April – May 1981 there were

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indications that the Soviets were preparing for a third try at entering the craft in commercial service. On 17 July 1981 the fifteenth (and probably last) TU 144 was produced—the first for twenty months. Earlier production had been envisioned to be forty to fifty units. As late as January 1982 flight training was reported as beginning once again at Shermetevo. Ministry of Civil Air officials confirmed that flights would continue even though results were “not up to expectations.”

In June 1983 a Tupolev engineer, writing in *Znamya* (Science), referred to the need for new engines for the TU 144, but referred to it chiefly in a nostalgic vein. Finally, the Ministry of Civil Aviation in a summer 1984 announcement noted that development of the SST had been brought to an end. Production cost alone had been estimated at \$2.8 billion. The Concorde R&D cost approached \$2.5 billion. On this analogue, the total cash cost to the Soviets of the “Concordski” would be in the region of \$4.5 billion.

Factors Contributing to the Failure of the Soviet SST

Forced draft development ordained by highest Soviet authority. This forced simultaneous development of all sub-systems. Unprecedented performance requirements for high speed and range required time for sufficient simulation of stress to anticipate design failures, but time was not available. The dangerously telescoped development cycle made sound design impossible. The political prestige gained by a record breaker was prodigiously expensive.

As a corollary, politicization of the research and development process. Its chief designer in 1977 claimed that the TU 144 was five percent higher, six percent longer, had a wingspan thirteen percent larger and twenty-two percent more wing area than the counterpart Concorde. This upsizing—almost certainly dictated by requirements that were political rather than technical or economic—destroyed what chance the aircraft had for aerodynamic efficiency. The focused espionage effort against Aerospatiale-Toulouse in the mid-1960s provided good data on the aerodynamics of the Concorde prototype. The decision to go up scale—without the computer capability to redesign the larger aircraft for maximum aerodynamic flow—undercut Soviet capability to produce a clean aircraft.

Soviet misperception that civil technology could not outrank military in sophistication and complexity. A civil airliner capable of Mach II for sustained periods poses technical demands much greater than those for a fighter-bomber. Requirements for economy, quietness, and passenger comfort were never resolved. What the Soviets flew was a raw, crude aircraft suitable for a military crew, but not for passengers—the fruit of decades of military domination in aviation.

Limited ability to exploit highly advanced Western technology obtained through espionage. The very high priority accorded SST data and technology in Soviet scientific and technical collection provided the Soviets with reams of material. [redacted] much of the data collected through espionage was “unintelligible” to Soviet technicians. Information that was understandable often set requirements beyond the capa-

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bilities of Soviet materiel and production technology. Incapable of copying the Concorde, the Soviets had to construct a parable.

Soviet decision to join the West at the technological frontier, rather than follow behind. Soviet infrastructure could not produce the equipment required to ensure commercially viable SST flight. Fifteen years of improvisation and patchwork never closed the gap. Avionics were always in an experimental state and the flight deck took on a finished look only in 1977.

Overcompartmentation and secrecy, fueled by interministerial rivalries and jealousies between the design bureaus. Soviet aircraft development is shared by the Ministry of Aviation Industry and the Ministry of Civil Aviation, though the respective spheres of responsibility are uncertain, possibly even to the Soviets. Tupolev was resented by other design bureaus as the favored design bureau, in the beginning because it received all the resources and credit for a project involving the whole industry, at the end because of its failure.

Technically inept development. Soviet skill in manufacturing titanium was not followed by its successful application to the airframe. Though the design target was that thirty percent of the aircraft's weight should be titanium, in practice this dropped to eighteen percent. This contributed to an overweight aircraft that crept up an additional fifty percent in weight over the course of its development. This in itself is not uncommon, but the commercial viability of the TU 144 was undercut by the inability of the engineers to extract more power from the engines. A thirty percent increase in thrust was achieved by 1972. Then development of the NK 144 engines apparently halted, though (b)(1) [redacted] concluded that proper flow analysis and tuning could have e(b)(3)(n) [redacted] another twenty-five percent increase in power from the engines. Because the weight creep was greater than the extra power coaxed from the engines, the actual speed and range of the TU 144 dropped as time went on. The problem was not solely that the engines lagged behind Western standards of performance, but that the Soviets lacked the ability to extract maximum results from their own equipment. This corroborates expert observation that there is a great gulf fixed between Soviet theory and application: though Soviet theoretical knowledge is second to none, shopfloor practice is often "crude blacksmith" work.

... As in the Russian fable of the Firebird, the Soviet political leadership had become intoxicated with its vision of the SST dancing in the wilderness beyond the USSR's technological reach. The Soviets had mounted a mighty effort to capture the secrets of supersonic commercial flight but came away bearing only the symbolic golden tuft of entries in the record books.

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